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Enhancing the End to End QoS of multi-media applications in mobile adhoc networks by an Integrated Cross Layer approach

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Abstract : The objective of this paper is to propose a novel method for enhancing end to end QoS of multimedia applications in mobile adhoc networks by using DiffServ approach and Multi Description Coding. The enhancement is achieved by implementing the Multi Description Coding (MDC) at application layer along with Connectionless Light Weight Protocol (UDPLite) in transport layer, Multipath routing and DIffserv at network layer. This approach achieves an increase of 36.84% in Peak Signal to Noise Ratio (PSNR) which is an improvement in PSNR and 20 % decrease in delay as compared to the conventional methods.

1 INTRODUCTION

Multimedia transmission in MANETs is subjected to both random and burst losses, which can deteriorate the quality of video delivered to the end user. With a number of solutions to tackle this crisis, Multiple Description Coding (MDC) with Multipath Transport (MPT) and DIffserv at network layer has been shown to be a capable scheme for video transmission over MANETs.

MDC the viable option for source coding is used in Application Layer. In MDC, the video file is split into sub-streams (each called a description) that have an identical significance. This enables each received unaccompanied description an assured fundamental level of reconstruction quality and other descriptions can augment the quality. Therefore if one description is lost it does not affect other descriptions thereby avoiding the retransmission of the description. The packets are then transmitted from Application Layer to the Transport Layer. At the Transport Layer UDPLite is used, which adds sensitivity information to the frames, thereby reducing the probability of dropping the frames and are sent to the Network Layer. In the Network Layer, a new multipath routing protocol SMMDSR is proposed and implemented[1]. To avoid congestion in links and to expeditiously utilize the Network resources, SMMDSR establishes multiple maximally disjoint paths and the packets are sent through the four routes separately and the packets are classified in the Edge router according to the priority specified by the Significant Video Information Random Early Detection Algorithm (SiVIRED).

In the past Yiting Liao and Gibson, J.D [2] proposed a Routing-Aware MDC (RAMDC) approach and Monica Aguilar Igartua and Víctor Carrascal Frías [3] proposed a Routing protocol that is able to self-configure dynamically distortion due to the packet skipping prior to the transmission. The limitation is that it is not suitable for reactive protocol. Shiwen Mao and Hou.Y.T proposed an application-centric cross-Layer approach. The limitation is that this concept is suitable for proactive adhoc routing paradigm and not for reactive protocol [4][5]. Gui et al [6] had proposed that for each description in MDC, certain packets are to be selected adaptively to skip before the transmission according to the bandwidth constraint of the underlying transmission path so that the impact of the skipped packet on the quality of the video is minimized.

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Wei Wei et al [7] projected heuristic interference-aware multipath routing protocols. The problem is the link information updated by Link State Advertisements (LSA) is an overhead and this concept is suitable for static Networks. Nawat et al [8] proposed a channel adaptive multiple description video codec with flexible redundancy allocation based on modeling and minimization of the end-to-end distortion. MDC has been discussed from the rate-distortion point of view [9] [10] [11]. MDC using transforms have been discussed [12][13] [14] [15] [16][17]. MDC techniques when the compression is present have been described [18]. More Work on MDC and its applications found in the literature are explained below. Ali C-Began et al [19], proposed that under the given traffic rate constraints, the quality of video rendered at the client is maximized by the packet scheduling algorithm. Shiven Mao et al [20] proposed a system to combine multi-stream coding with multipath transport, by exploiting path diversity in Adhoc Networks. The drawback in the system was sending feedback to source which is an overhead in MANETs.

Ali C. Began et al [21] integrated the Application and Network Layer functionalities in their new framework for video. Sudheendra Murthy et al [22] intended different path selection algorithms for multipath computing which can be used with MDC and layered coding techniques.

Shernan Lin et al [23] discussed that for video transmission in Adhoc Networks a feedback reference picture selection scheme can be used. Yiting Liao et al [24] presented that to enhance the transferred video quality over the indolent Network a Refined Error Concealment (REC) method on a Macro Block (MB) basis can be used.

Yao Wang et al [25] proposed a multiple description coding that generates two descriptions containing the even and odd coded frames. When packets in either description are lost, a second order predictor is used, to suppress the error propagation. Brian A. Heng et al [26] proposed an adaptive MD coding approach. In their approach the end to end distortion of the path is measured accurately by the encoder and based upon that the paths have been used effectively. Shiwen Mao et al [27] proposed a MD coding along with multicast for adhoc Networks. David Comas et al [28] proposed an unbalanced MDC video system for H.263 video decoder.

John G. Apostolopoulos et al [29] discussed on Content Delivery Networks. Patricia Acelas et al [30] implemented Multiple Description Coding (MDC) technique for improving video quality. Yen-Chi Lee et. al [31] discussed layered coding and MDC and concluded that error protection should be used for error prone Networks. The approaches discussed in [19]-[31] requires the knowledge of the Networks a priori. In the proposed work along with MultiDescription Coding in Application Layer, The Split Multipath Multimedia Dynamic Source Routing (SMMDSR) protocol along with SIVIRED Active Queue Management algorithm has been proposed in this paper. To provide a better QoS to the multimedia applications many protocols that support QoS have been proposed. Two mechanisms such as Integrated Services and Differentiated Services (DiffServ) have been incorporated in Internet applications to provide Qos for all bandwidth sensitive applications. Multiple classes of service can be chosen by the application Layer through the Integrated Service Model with the help of a resource reservation protocol such as RSVP. RSVP [32] provides QoS by reserving resources, such as bandwidth, during the signaling process. Bandwidth limitation and the frequent topology changes in MANETs make this solution inconsistent for MANETs. First, MANETs are bandwidth limited, and the associated overhead for control (signaling) packets may cause congestion in the Network. Second, topology changes often cause established routes to fail [33]. In contrast to Integrated Services which uses RSVP, the DiffServ is used [34], where the traffic is grouped into a small number of forwarding classes called as Aggregations or classes that have similar QoS requirements, and resources are assigned on a per-class basis.

In DS aggregations are forwarded at each node following the Per Hop Behavior (PHB). The PHB is selected by a mapping between a code point that identifies the aggregation and the expected behavior has been proposed by Jacobson et al [35]. The two PHBs that are proposed by Davie et al and Heinanen et al, are the Expedited Forwarding (EF) PHB [36,37] and Assured Forwarding PHB. Ziviani et al proposed the Assured Forwarding (AF) PHB [38]. Although research works by Dovrolis et al, Hao et al, Ziviani et al and Koenen et al [39] [40][41][42] consider distinct aspects of differentiated services, the transmission of video traffic over a DS enabled Network has been discussed. The Scheduling algorithms decides which packet to be send next and controls the allotment of the bandwidth among flows [43] when the traffic is high. The scheduling algorithms that are projected in [44]. make the Internet a QoS-capable Network

Various active queue management algorithms have been proposed for streaming multimedia in wired Networks. The most widely used queue management algorithm is Random Early Detection (RED)[44]. RED detects congestion by computing the average queue size. When the average queue size is exceeded, the gateway drops or marks each arriving packet with a certain probability. If the packet is not marked it is forwarded. Most AQM mechanisms drop packets randomly without differentiating their importance [45-47]. Though the research works proposed by Yu-bao-Cui et al, Scong-Ryong Kang et al and Xu et al [45][46][47] use AQM and DiffServ for video streaming, these methods are not suitable for MANETs.

The available queue management algorithms include RIO [48], Weighted RED (WRED) [49], WRED with Thresholds (WRT) [50], that are able to differentiate packet priorities but considering the video packets as normal packets. Gabriel et al [51] presented that, for multimedia applications, the traffic crossing the Network has inter packet dependencies due to application-level encoding schemes.

Changhee Jooet et al [52] developed random access scheduling scheme and Cheng-Han Lin et al [53] proposed an Enhanced Random Early Detection Forward Error Correction (ERED-FEC) mechanism for multimedia traffic in wireless Networks. Chung et al [54] proposed a protocol using a priority based queue management along with RED approach. Zivani et al [55] proposed a technique using differential service for MPEG-4 video streams. Shujie Wei et al [56] proposed a technique for estimating the bandwidth in MANETs for video streaming. The concepts discussed in [54] [55][56] has not improved the performance of video streaming in MANETs. Zheng Wan et al [57] proposed a priority based video coding algorithm. This algorithm used the idea of unequal protection to improve the quality of video in MANETS. Yan Li et al [58] proposed Autonomic Active Queue Management (AAQM). Ziviani et al [59] proposed Forward Error Correction (FEC) scheme to MPEG-4 encoding, in a Differentiated Services environment.

Bulent et al [60] discussed the service class distribution for real-time MPEG-2 video transport. Long Le et al [61] proposed Proportional Integral (PI) controller, the Random Exponential Marking (REM) controller and Adaptive Random Early Detection (ARED) for wired Networks. Lishui Chen et al [62] proposed a two marker delivery system for delivery application over DiffServ Networks. So far no work has been carried out using AQM and DiffServ in MANETs.

So this research work aims at another approach for effective queue management in routers. MDC and SMMDSR and Significant Video Information Based Random Early Detection (SiVIRED) which is an Active Queue Management (AQM) mechanism has been proposed in this work along with UDPLite in Transport Layer for increasing the delivery quality of video streams over MANETs. In MANETs, routers implement active queue management schemes, such as RED with In and Out (RIO) [48] and provide service differentiation to the traffic according to pre-assigned service classes and drop priorities carried in the packet header.

In [63] Floyd et al, the adaptive RED or active RED (ARED) algorithm infers whether to make RED more or less aggressive based on the observation of the average queue length. [47] NRED is an extension of the original RED scheme. K. Xu et al [47] assumed that each node keeps estimating the size of its neighborhood queue (distributed queue). But in the MANETS the nodes in the topology would not cooperate that much because the topology will change very frequently. So cooperation cannot be expected.

To overcome the limitations in the previous works, Multiple Description Coding (MDC) in Application Layer, UDPLite in the Transport Layer and Split Multipath Multimedia Dynamic Source Routing (SMMDSR) in Network Layer and SiVIRED algorithm is proposed in this paper. The remainder of this paper is organized as follows: Section 2 and Section 3 deals with the proposed system and the Multipath routing are discussed. Section 4 depicts the SiVIRED algorithm. Section 5 depicts the system simulation model and illustrates the significance of the proposed work, while conclusions drawn are given in section 6.

2. CROSS LAYER ARCHITECTURE

Provisioning Quality of Service (QoS) for multimedia applications in Adhoc Networks is a challenging task. The QoS provided by the MANET depends on the coordination efforts from all layers. Hence, it is really advisable to develop dynamic solutions based on Cross Layer approaches that are able to take QoS provisioning into account in the different technical specifications of the TCP/IP protocol stack. This paper aims at enhancing the Quality of Service of video streaming by proposing a new Cross Layer approach for Mobile Adhoc Networks.

In this Cross Layer Architecture, Video streams are fed to the Application Layer. This video source file is coded into multiple descriptions and is compressed using the MPEG-4 standard and fed from the Application Layer to the Transport Layer. At the Transport Layer, UDPLite includes sensitivity information to the frames thereby reducing the probability of dropping the frames and sends it to the Network Layer.

To provide stable and reliable communication, multiple paths are preferred in the Network Layer so that the limitations due to bandwidth and time-varying nature of the topology can be overcome. The Split Multipath Multimedia Dynamic Source Routing (SMMDSR) protocol along with SIVIRED Active Queue Management algorithm has been proposed in this paper that provides very good Peak to Signal Noise Ratio(PSNR)and a smaller end to end delay. Due to the availability of more number of paths in the network layer, the requirement of multimedia applications has been satisfied. Likewise, at the receiving side, the packets from various paths are collected in the Network Layer and sent to Transport Layer. Packets containing corrupted header portion are discarded and the remaining packets will be merged by merger at the Application Layer that merges all the received descriptions and sends to media player.

The framework for evaluating the proposed Cross Layer system is shown in the Figure 1. The input source for the framework is a raw video sequence in YUV CIF (176 x 144) format of size 15MB

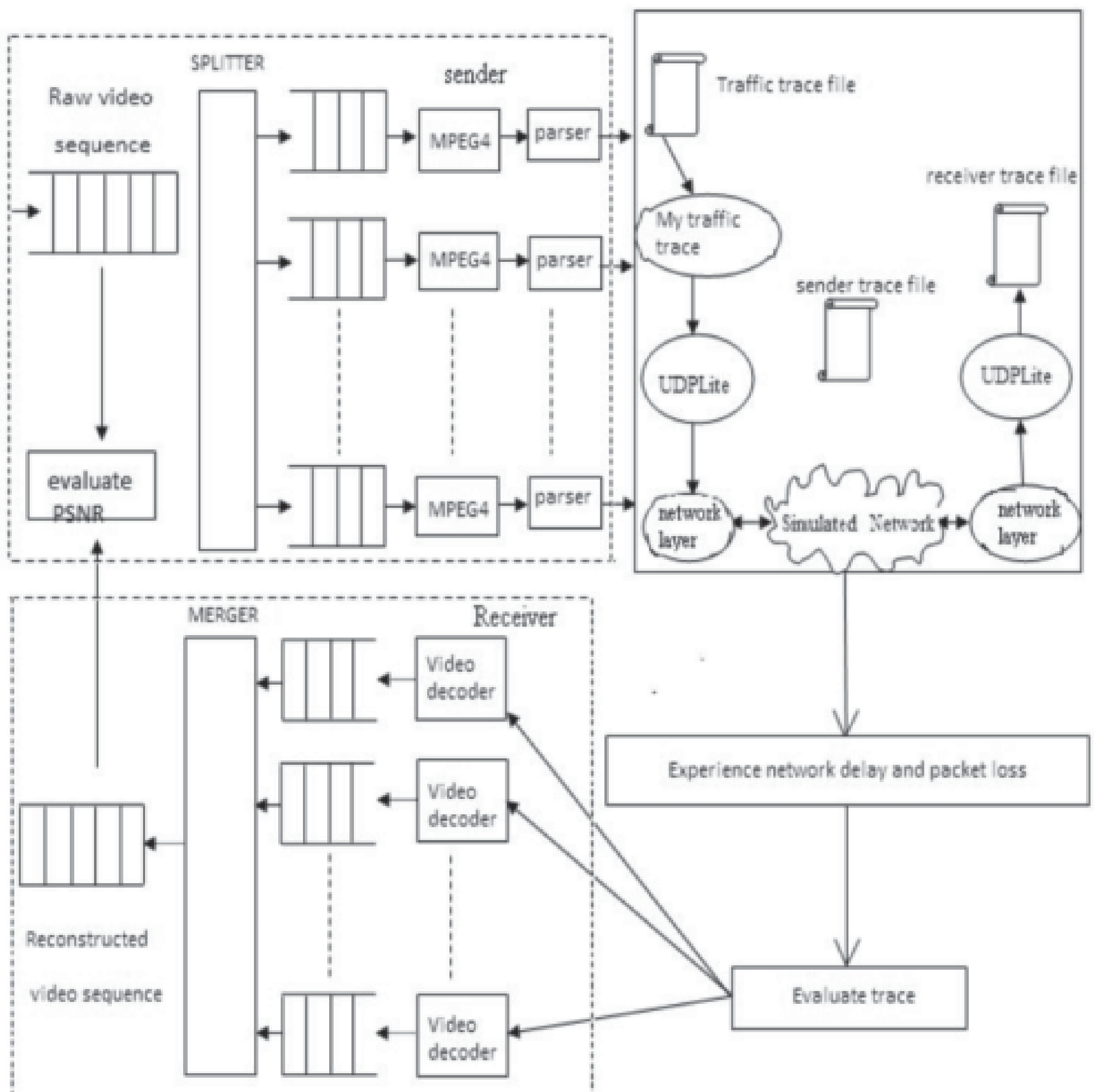

Fig. 1. Framework for Cross Layer Architecture

The source file is split by the splitter into 4 descriptions using a frame based approach. The split video sequences are MPEG-4 encoded and each compressed video sub stream is parsed by the parser program which generates a trace file which consists of frame-id, frame-type, frame-size and entitled sending time. The records in the traffic trace file are read by the application and the application generates the corresponding packets in the Network simulator. The generated packets are sent to the lower UDPLite Layer by the application according to the user specified time. The output file name of the sender trace file is specified by the user in UDPLite agent. The timestamp of each transmitted packet, the packet ID, and the packet size are also recorded by the agent.

The packets sent to the Network Layer are routed by SMMDSR protocol through multiple disjoint paths. Five paths are identified by this protocol and out of which four paths are used for sending the packets and one path is kept as a stand by path. The four descriptions are sent through 4 different disjoint routes. Thus more number of packets sent from one end of the Network Layer on the sending side to another end router in the receiving side.

At the receiving side, Physical Layer receives the video data and it is transmitted to UDPLite Sink through MAC Layer and Network Layer. UDPLite Sink is the receiving agent for UDPLite. The timestamp, packet ID, and size of each packet that is received in the user specified file are recorded by the sink agent. After the simulation the evaluate trace checks the sender trace files and the receiver trace file. The number of records in both the trace file is calculated. From the evaluation trace file, the number of packets that are sent and received become known. Moreover, a distorted video file which corresponds to the corrupted video is formed at the receiver side.

After decoding each video file which had been received, the actual video is reconstructed using merger. The merger program generates the reconstructed video sequence from the decoded distorted video sequences which are fed to the merger program by the decoder. The number of video frames in the primitive video should be equal to the total number of video frames in the reconstructed video sequence. If it is not equal, the merger program does error concealment by copying the last successfully decoded frame of the sub-stream to the lost frames until a correct decoded frame is identified.

3. MULTI PATH ROUTING

In this work five paths are selected and hence 5 paths are available always, of which one path is kept as a stand by route. The five routes are chosen in order to send the four video descriptions through four routes and in case if one route fails, the stand by path can be used to send the video data so that the video is sent. In Split Multipath Multimedia Dynamic Source Routing protocol how the five routes are chosen is explained below.

In the Split Multipath Multimedia Dynamic Source Routing protocol, the source transmits RREQ packets to discover the routes. The destination node sends a Route Reply (RREP) back to the source node. More RREQs are received by the destination node after a period of time. Among the received RREQs, the destination selects the route that is maximally disjoint to the first replied route and sends another RREP to create the second route and this way five routes are created. Among the five routes four routes are chosen and four video descriptions are sent through these separate four routes to achieve low delay and good quality multimedia streaming.

If five routes are not available and only four routes are available, then four descriptions are sent through four routes. If Only three routes are available three descriptions will be sent through the three routes and the received quality of video will be reduced from 52dB to 49 dB in PSNR and only if two routes are available then the PSNR is reduced to 47dB.

If 5 paths are not available to reach the destination then the intermediate node will send the node not reachable error message to the source.

In the proposed MDC with SMMDSR and SiVIRED approach using DiffServ, several modifications have been incorporated to DiffServ to make it useful in Mobile adhoc Network. The DiffServ architecture distinguishes two parts:

1. The core Network which does packet forwarding and
2. The edge router performs categorization of the incoming traffic and labeling them according to application types.

The core router and edge router classification in a static Network is easy. This type of classification does not hold in MANET. In MANETs, since each node has a capability to perform like node and also a router, in this paper the core router and edge router are considered as two functionalities instead of two separate categories of routers. These two functionalities are present in each node. The node while receiving a packet, the Functionality Selector (FS) in each node looks at the packet header and forwards the packets either to edge router functionality or the core router functionality. If the FS in the node receives a packet and if it finds that the node is the neighbor to the source node, then it forwards packet to edge router functionality and similarly in the receiving side when the node before the destination node receives a packet if it finds that the next hop is the destination, then the functionality selector forwards the packet to edge router functionality. For the remaining cases, the Functionality Selector forwards the packet to core router functionality. Due to the Functionality Selector (FS), the PHBs are configured by itself. The incoming traffic is checked and it is done by edge router and also it does marking of packets according to TOS field of IP packets, while core router just looks for TOS field and forwards the packets according to the PHB.

The Edge router maintains three virtual queues for three video frames inside the physical queue as depicted in Figure 2.

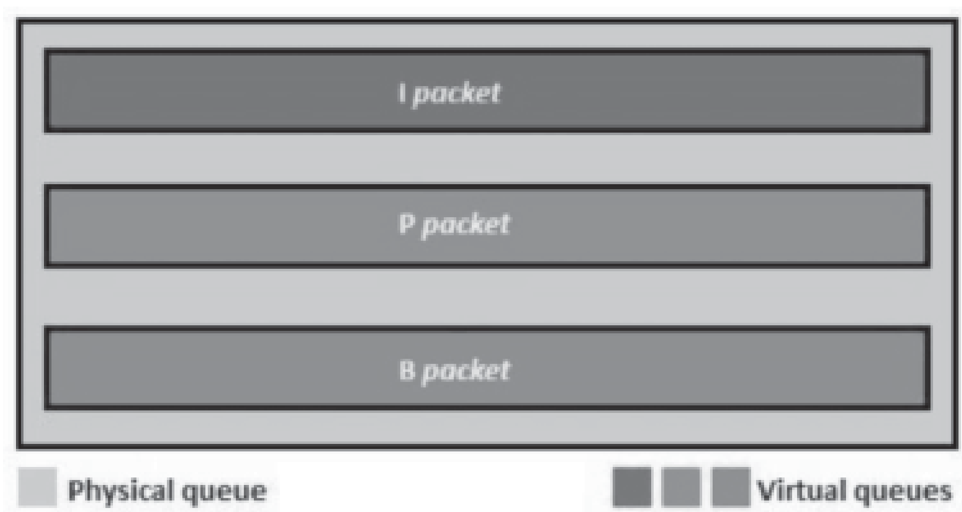

Fig. 2. Virtual queue for SiVIRED

SiVIRED AQM algorithm is implemented in edge routers that provide service differentiation to the video traffic. The service differentiation is done based on the pre-assigned service classes and video packet drop priority which is done by the video source and that information is specified in the packet header. Significant Video Information Based Random Early Detection (SiVIRED), combines the capabilities of the RED algorithm with video Precedence (I packet > P packet > B packet). This combination provides a preferential traffic handling, with the highest priority video packets being handled first and then the lower priority video packets are handled later. It selectively discards the lower priority traffic when the queue begins to get congested.

4. SIVIRED ALGORITHM

In SiVIRED algorithm, virtual queues are created in a physical queue of the router. Different RED parameters are used for the virtual queues, inducing packets from any one of the virtual queue to be dropped more often than packets from the other. Consider three RED buffers (three virtual queues).

The precedence for drop of video packets is provided by making differentiation in the packets so that the delivery and quality of video stream is increased. The marking for drop differentiation of video packets takes place at the video source based on the type of MPEG frame namely I, P, B frames. The generated video information at the Application Layer is mapped to the Type of Service (TOS) of DS field in IP header. The TOS field contains the premarked video priority information. I-frame packets are marked with the lowest drop probability and P-frame packets are marked with a medium drop probability, B-frame packets are marked with the highest drop probability. According to the priority information and service differentiation defined by the, SiVIRED AQM algorithm in edge routers the video traffic is handled.

When the queue gets accumulated in edge router with video packets and transcends a given threshold, the SiVIRED begins to drop packets following the specified drop probability parameters. Significant Video Information Based Random Early Detection (SiVIRED), unites the capabilities of the RED algorithm with video Precedence (I packet>P packet>B packet). This combination affords preferential traffic handling for higher priority video packets and lower priority video packets than conventional traffic. It can discriminate and reject lower priority traffic when the queue begins to get overfilled.

The average queue size is calculated and compared with two thresholds namely maximum threshold (maxth) and minimum threshold (minth) by the SiVIRED algorithm. The packets are not marked if the average queue size is less than the minimum threshold. The packets are dropped if the average queue size is greater than the maximum threshold. When the average queue size is between the minimum and maximum thresholds, each arriving packet is noted with probability pa, where pa is drop probability which is a function of the average queue size.

The threshold parameters of SiVIRED mechanism for IPB packets are configured to the percentages of the total number of packets which is assumed as 50 (queue length). The maximum threshold (maxth) parameter value is assigned as 0.8*queue length and minimum threshold (minth) is assigned as 0.6*queue length and maximum dropping probability (Pmax_I) is assigned as 0.016 for I Packet. Maximum threshold parameter (maxth) for P packet is assigned as 0.6* queue length and minimum threshold (minth) is assigned as 0.4*queue length and maximum dropping probability (Pmax_B) is assigned as 0.02. For B packets and maximum threshold parameter(maxth) is assigned as 0.4* queue length and minimum threshold (minth) is assigned as 0.2*queue length and maximum dropping probability (Pmax_B) is assigned as 0.03 respectively. The weight of queue (wq) is assumed as 0.002.

The Figure 3 depicts the parameters used in SiVIRED.

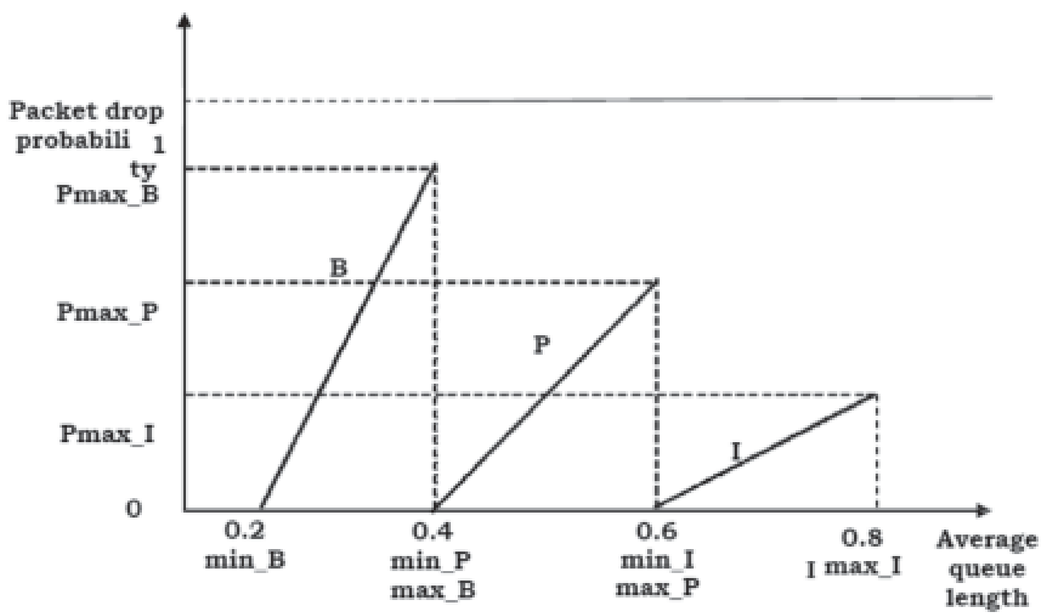

Fig. 3. Parameters of ViVIRED mechanism with 2 Level_I

In [63] Floyd et al, the adaptive RED or active RED (ARED) algorithm infers whether to make RED more or less aggressive based on the observation of the average queue length. If the average queue length oscillates around min threshold then early detection is too aggressive. On the other hand if the average queue length oscillates around max threshold then early detection is being too conservative. So the ARED active Queue management algorithm does not control the video traffic in MANETs properly, the delay is more as shown in Figure 10 and the PSNR is very high when compared to ARED as shown in Figure 9.

K. Xu et al [47] assumed that each node keeps estimating the size of its neighborhood queue (distributed queue). Another assumption is once the queue size exceeds a certain threshold, an overall drop probability is computed by the algorithm of NRED and this overall drop probability is propagated to all the nodes in the neighborhood nodes. The neighborhood nodes starts dropping the packets. But in the MANETS the nodes in the topology would not cooperate that much because the topology will change very frequently. So cooperation cannot be expected. The second Point is nodes will send neighborhood congestion notification Packets to the neighborhood nodes again which is time consuming and those packets will be utilizing the channel bandwidth during the congestion resulting in high delay as shown in Figure 4. PSNR

Thirdly no priority has been given to the packets so all the packets will be given equal preference while dropping the packets during congestion. So using NRED algorithm in the Diffserv architecture for video streaming in MANETs is not beneficial.

In the proposed method MDC and SMMDSR and SiVIRED has been used so that highest priority has been given to video packets.

5. SIMULATION RESULTS AND DISCUSSIONS

On the whole, the results obtained were based on the simulation setup for MDC along with UDPLite and multipath scheme and SiVIRED Algorithm. The MDC along with UDPLite and SMMDSR and SiVIRED Algorithm and over an adhoc Network have been simulated using MPEG-4 encoder and NS2 simulator and performance of the received video at the receiver has been examined. In the simulation, the proposed MDC along with SMMDSR and SiVIRED method and ARED method are compared. In SMMDSR with MDC, five paths were considered and the four descriptions were sent through four paths. The video sequence"Foreman", is at QCIF format with 400 frames.

Table 1. Simulation Parameters for MDC with Multipath routing and SiVIRED Algorithm.

Parameter	***Value***
Area	500 × 500m
Number of Mobile Nodes	20 nodes
Mobility Model	random waypoint model
Speed	(0 < 5) m/s
Routing Protocol	SMMDSR
Traffic type	VBR/UDPLite
Queuing schemes	SiVIRED
Buffer size	50 packets
MAC protocol	802.11e
Video	Foreman YUV QCIF

The Multiple Description Coding with SMMDSR concept performs well when compared with Routing Aware MDC and other related works.

Figure 4: PSNR value of the proposed MDC along with SiVIRED algorithm and the ARED .

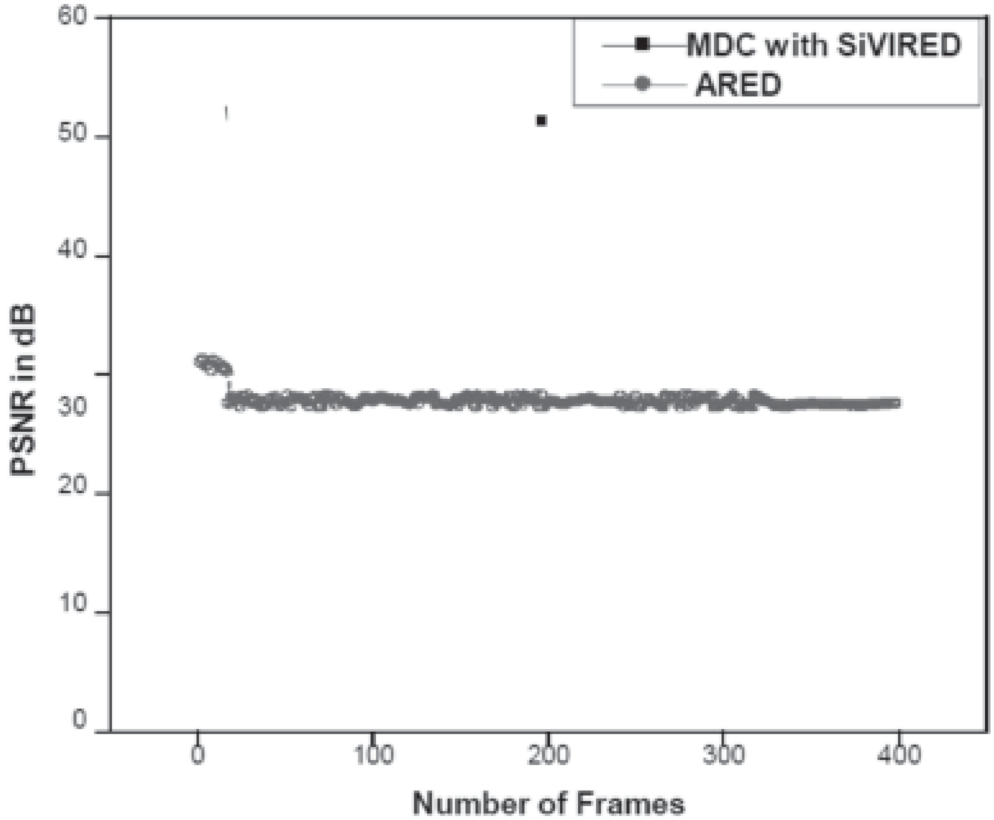

Fig. 4. Shows that the proposed approach outperforms all the related approach in terms of PSNR.

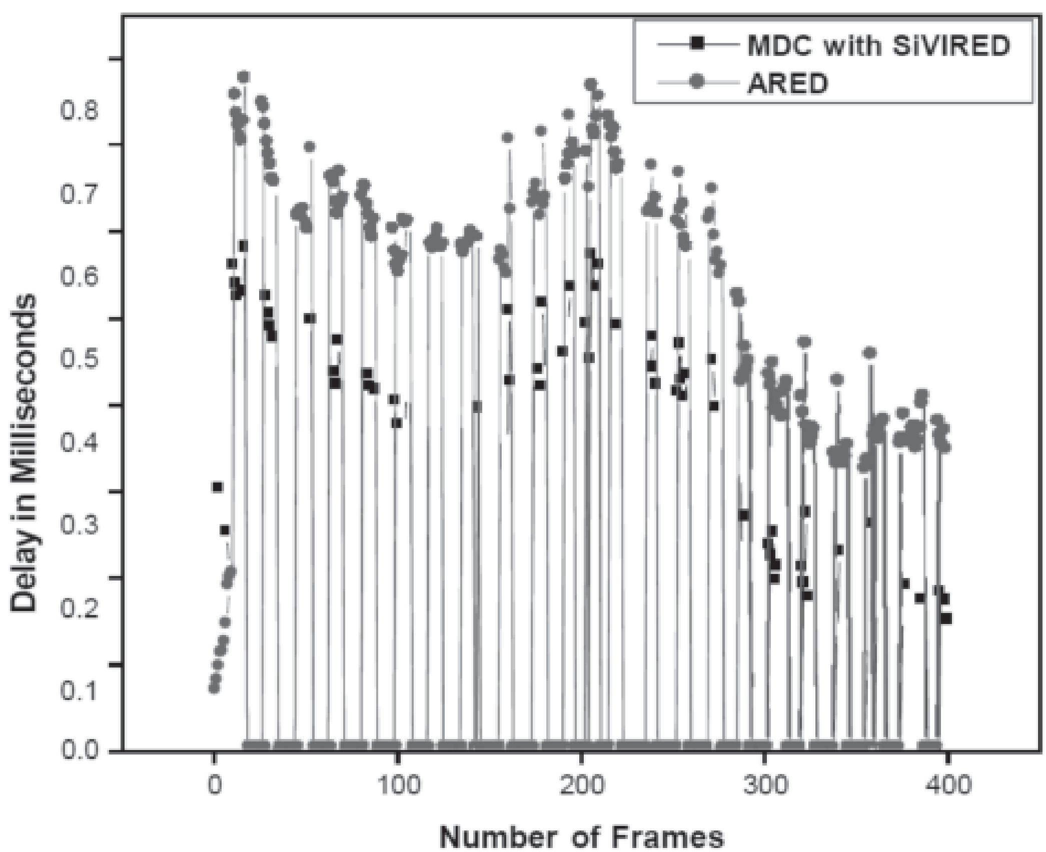

Fig. 5. Delay produced by MDC with UDPLITE and SiVIRED algorithm with other related approach for Foreman video.

6. CONCLUSION

The Multi Description Coding along with UDPLite and multipath transport and SiVIRED are proposed to enhance the quality of video transmission over Mobile adhoc Networks. The simulation results show that the proposed approach achieves an increase of 36.84% in Peak Signal to Noise Ratio (PSNR) which is an improvement in PSNR and 20 % decrease in delay as compared to the conventional methods.

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